Bull. Environ. Contam. Toxicol. (1991) 46:697–704

Bulletin of Environmental Contamination and Toxicology

Effect of Pesticide Formulation on Transmission: A Comparison of Three Formulations

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The minimization of dermal exposure to pesticides is critical in reducing the health risks associated with the handling of toxic chemicals. In the past decade, protective apparel has been recognized as an effective method of reducing these risks (DeJonge et al. 1985). Previous research has focused on the barrier effectiveness of this apparel examining the influences of fiber, yarn, fabric construction and fabric finishes and garment design (DeJonge et al. 1985; Leonas et al. 1989; Raheel and Gitz 1985; Slocum et al. 1986). The effectiveness of protective clothing is further affected by characteristics of the pesticide, including the formulation and active ingredient. Pesticide formulation refers to the form that the pesticide is in when it is purchased. The formulation contains various chemicals in addition to the active ingredient to aid in the ease of preparation and application. Staiff, Davies, and Stevens (1982) compared the transmission of wettable powder, emulsifiable concentration and flowable formulations of the same pesticide and found the emulsifiable concentrate transmitted through the fabrics more readily than the other formulations tested.

This research was designed to compare the transmission of three pesticide formulations--dust, spray and liquid--through selected fabrics. In addition, differences due to manufacturers (within formulation groups) were considered. Three fabrics of varying fiber content and construction were used in this study.

MATERIALS AND METHODS

Ten pesticides representing three formulations, three different active ingredients and three manufacturers were used in this study (Table 1). An incomplete block

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Table 1. Pesticide Description

	Common Name	Formulation	Active Ingredient	Manufacturer
1	Ortho Klor--indoor and outdoor insect killer	Dust	Chlorpyrifos	Ortho
2	Indoor-outdoor insecticide	Liquid	Chlorpyrifos	Dursban
3	Outdoor ant, flea,and cricket spray	Spray	Chlorpyrifos	Ortho
4	Lawn and garden insect control	Liquid	Diazinon	Spectracide
5	Diazinon insect spray	Spray	Diazinon	Ortho
6	Garden rose and houseplant spray	Spray	Diazinon	Spectracide
7	Garden insect dust	Dust	Diazinon	Spectracide
8	Soil and foliage dust	Dust	Diazinon	Ortho
9	Liquid Sevin	Liquid	Carbaryl	Ortho
10	Sevin garden dust	Dust	Carbaryl	Ortho

design with random sample exposure to pesticides was used. The three formulations included dust, prepackaged spray and liquid. These formulations are commonly available for a wide range of pesticide products. The pesticide products from the manufacturers and active ingredients was selected to ensure results would not be unique to a specific product, but rather would be representative of available products.

Three fabrics representing those commonly used in apparel were selected as the test fabrics in this study. A 100% cotton twill weave construction (Fabric A), a 100% cotton plain weave construction (Fabric B) and a 65/35 cotton polyester plain weave (Fabric C) construction were the test fabrics used. Fabrics were obtained from Test Fabrics, Inc. of Hoboken, N.J. and cut to 15.24 x 15.24 cm^2 samples. The fabric samples were combined to form a four-layer composite sample as described by Leonas & DeJonge (1986) and exposed to the pesticide product. The amount of pesticide that transmitted the test fabric (layer 1) was determined by calculating the amount of pesticide found on the collector layer (layer 2) and the first foil layer (layer 3). The second foil layer (layer 4) was discarded. The collector layer used in this study was a 50% cotton/50% polyester blend jersey knit fabric (tee-shirt fabric). All fabrics were prewashed to remove auxiliary chemicals prior to exposure to the pesticides.

The fabric samples were exposed to the equivalent of 1 gram of pesticide formulation containing 1.25% active ingredient. The liquid formulated pesticides were pipetted onto the central region of the multi-layer samples in concentric circles using a programmable pipette following established methodologies (Raheel and Sitz, 1985). The pesticides in a dust formulation were sprinkled onto the central region of the multi-layer sample while holding the container 20.23 cm above the test fabric. The pesticides in the spray formulation were applied holding the spray can nozzle 30.58 cm above the test fabric surface. The length of spraying time was calibrated so that an accurate amount of pesticide spray was delivered to each sample. The multi-layer samples were weighed before and after exposure to ensure 1 ± .01 gram was applied for the dust and spray formulations. After exposure, the fabrics remained undisturbed for 1 hour. This allowed the liquid and spray pesticide formulation to dry. A 7.26 x 2.54 cm strip specimen was then removed from the center of the fabric sample and the pesticide extracted using the procedure developed by Easter et al. (1983). Two 1 μl injections of each pesticide extract were analyzed using gas chromatography techniques. The amount of pesticide that transmitted the test fabric, as found on the collector and foil layers, was determined. A Packard Model 438A gas chromatograph with a nitrogen phosphoruous thermionic detector was used for analysis of the extract. A glass column 3 ft x 2 mm with 5% apiezon and 0.125 degs on 100/120 meshsize suplecoport was used. For the pesticides containing chlorpyrifos and diazinon, a column temperature of 180°C and detector temperature of 250°C were used. For carbaryl containing pesticides, a column temperature of 170°C and detector temperature of 250°C were used. Blanks were placed between all injections to ensure no carryover of pesticides and external standards were included after every 10 injections to ensure accurate calibration of the equipment.

RESULTS AND DISCUSSION

The mean quantity of pesticide found on the collector and foil layers is in Table 2. An Analysis of Variance (ANOVA) with post hoc analysis showed that there were significant differences among formulations and fabrics; however, manufacturer was not a significant factor in this study (Table 3).

Table 2. Pesticide Transmission through Fabrics

Pesticide	Formulation	Amount Fabric A	Pesticide Transmitted (ug/cm^2) Fabric B	Fabric C
1	D	6.5569	8.5167	12.8699
2	L	44.0169	75.7100	78.0576
3	S	65.8113	62.5967	87.7665
4	L	92.4438	70.3291	73.6680
5	S	32.2967	81.663	101.4987
6	S	24.5647	57.2873	81.6450
7	D	5.1030	3.8747	5.4753
8	D	1.0132	2.7849	2.7585
9	L	7.5017	10.974	19.1760
10	D	3.648	5.592	6.0814

D - Dust, S - Spray, L - Liquid

Table 3. ANOVA for Differences in Pesticide Formulation

Model	df	PR>F*
Formulation	2	0.0001
Manufacturer	2	0.0542
Fabric	2	0.0153

*PR<.05 indicates significance.

Greater amounts of the spray and liquid pesticide formulations were found on the collector layers when compared with the amount of pesticide from the dust formulation. There was no significant difference between the amount of the spray and liquid that was transmitted; rather they were similar as demonstrated by the ANOVA post hoc analysis (Table 4). This analysis shows strong agreement between the statistical methods, each one has an F value of 0.94. With the F value close to value of one (1), it shows great similarity between the spray and liquid formulations.

Table 4. Post Hoc Analysis of Spray and Liquid Formulation

Statistic	PR>F*
Wilk's Lambda	0.9430
Pillar's Trace	0.9430
Hotelling-Lawley Trace	0.9430
Roy's Greatest Root	0.9430

*As F approaches 1 there is greater similarity among treatments.

The movement of the pesticide through the fabric is directly related to the nature of the pesticide solution and its movement and the particle size (Pratt and Littig 1974). The transmission of liquids is comprised of three distinct steps: 1) adsorption, 2) absorption, and 3) desorption. Adsorption is controlled by the relationship between the surface energy of the fabric and the surface tension of the liquid. As the differences between these measurements decrease, adsorption is more likely to occur. The absorption describes the sorption of the pesticide into the fabric structure. This movement is controlled by the fabric structure and particle size. The fabric structure is fundamental in determining the size and shape of the fabric openings or pores. The smaller the pore size, the less transmission will occur. If the particle is large, it will not readily penetrate the structure as the fabric acts as a filter or barrier preventing further movement of the particle. The particle becomes trapped within the fabric structure preventing transmission through the fabric.

In the spray and liquid formulations the active ingredient is suspended in a liquid (usually primarily water). Surface active agents and oils are added to form a stable suspension and so the pesticide will adhere to the intended target. These additives reduce the difference between the surface tension of the solution and surface energy of the fabric. This results in more rapid adsorption when the solution initially comes in contact with the fabric surface and as it moves through the fabric structure. The liquid also acts as a carrier to move the pesticide to the desired location. The low viscosity of the liquid, being produced primarily from water, allows for easy movement through the fabric structure, carrying the pesticide with it.

If the suspended pesticide particle is large enough, it may become trapped within the fabric structure (between the yarns or fibers) preventing transmission. If the particle is in a liquid state, it can be dislodged and continue moving through the fabric structure. Particle size is controlled by the formulation and method of application. Particle size can be no larger than the droplet size created by the spray. In this study the spray was classified as a coarse spray containing droplets greater than 400 microns in diameter (spray classification according to Pratt and Littig 1974). The liquid formulations were applied using a pipette so the liquid was not broken into droplets. However, there was more liquid in a smaller area and the pesticide particle was carried through the fabric for this formulation.

The dust had the fineness of powder and it was not possible to separate individual particles for measurement. However, with no liquid to carry the pesticide through the fabric, high levels of transmission to the collector layers did not result.

In this study, the liquid carrier present in the liquid and spray formulations influenced the transmission of the pesticide through the fabrics. The pesticide moved along with the liquid resulting in greater transmission.

The twill fabric allowed less transmission than the other fabrics included in this study. This results in the particles being trapped more readily in the twill fabric and less occurrence of transmission. The twill fabric with its irregular interlacing pattern requires the pesticide to twist through the fabric unlike the plain weave fabrics which have a simpler interlacing pattern. These results support previous research specifically designed to identify fabric characteristics responsible for limiting pesticide transmission (Leonas et al. 1989; Leonas and DeJonge 1986; Raheel and Gitz 1985).

There was a trend indicating the cotton plain weave fabric allowed less pesticide transmission than the cotton/polyester blend plain weave fabric. Cotton fibers have an irregular surface with a kidney bean type cross section. The polyester fibers used in this fabric had a circular cross section. The irregular surface of the cotton fibers allows for the pesticide particle to be trapped by the fiber as it moves through the fabric reducing transmission. In the blend fabric there were less available fibers capable of trapping the particle. This supports previous research that cotton fabrics allow less transmission than polyester or cotton/polyester blend fabrics (Leonas et al. 1989).

Our results indicate that the dust pesticide formulation does not transmit through fabrics as readily as the liquid or spray pesticide formulations for the products and fabrics evaluated in this study. The liquid acts as a carrier moving the pesticide particles through the fabric. In this study, the manufacturer of the pesticide was not a significant factor influencing transmission.

The fabrics used provided significantly different levels of transmission. Generally, the 100% cotton twill fabric allowed lower amounts of pesticide transmission than the plain woven fabrics. This supports findings of previous research specifically examining fabric characteristics.

These results increase our knowledge of pesticide transmission as it is influenced by pesticide characteristics of formulation and manufacture. Further study is needed to assess the transmittance of additional pesticide formulations and to evaluate the mechanism of transmission.

The results of this study will be helpful in selecting pesticide formulations that are less likely to transmit barrier fabrics worn during the application and handling of pesticides.

Acknowledgements. This project was supported by the Agricultural Experiment Station funds, University of Illinois under project RRF-HRFS-NC 170. Gas chromatography analysis was completed by YiJun Wang, Research Assistant in the Division of Consumer Sciences in the laboratory, and in the laboratory of Dr. Allan Felsot at the Illinois Natural History Survey.

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Received August 10, 1990; accepted November 14, 1990.